STRATIGRAPHY AND PALAEONTOLOGY OF THE DRAKE AREA, NEW SOUTH WALES

P. G. TELFORD
Department of Geology and Mineralogy, University of Queensland, Brisbane

(Communicated by Professor Dorothy Hill)

(Plate XVI)

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Synopsis

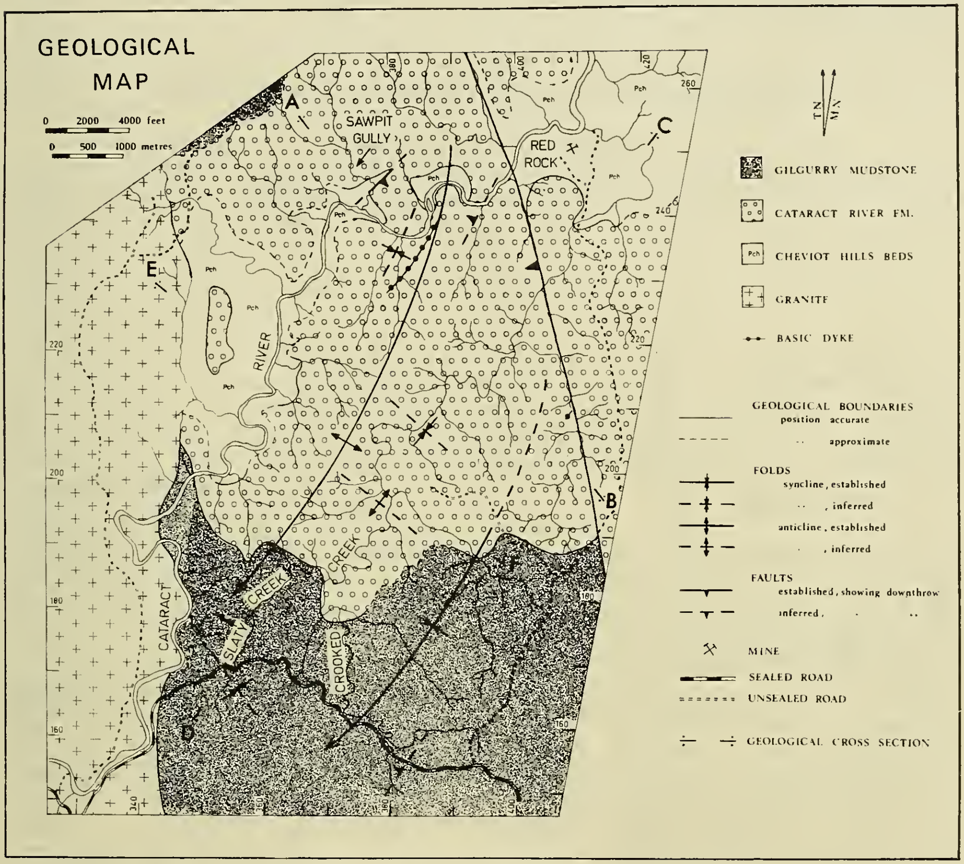
Permian strata bordering the New England Batholith west of Drake, New South Wales, are gently folded into northerly trending anticlines and synclines. The lowermost unit, the Cheviot Hills Beds, consists of over 5,000 feet of volcanic rocks, and it is conformably overlain by the 900–1,600 feet of interbedded volcanic rocks and mudstones of the Cataract River Formation. Conformably overlying this formation is the 1,900 feet thick Gilgurry Mudstone which is the youngest marine Palaeozoic unit in the Drake area. Assemblages of fossils from mudstones in the various units are typical of Dickins's (1964) Fauna IV which is probably of Upper Permian (Kazanian) age. Structural and stratigraphic relationships of the Permian succession west of Drake with Upper Palaeozoic sequences north-east of Drake and near Warwick in Queensland are discussed.

INTRODUCTION

During the late nineteenth and early twentieth centuries the Drake district, situated about thirty miles east of Tenterfield in northern New South Wales, was an important gold-, copper-, and silver-producing area. Early geological work was concerned mainly with these mining activities (David, 1887; Jaquet, 1897) and little attention was given to regional aspects of the Upper Palaeozoic strata in the area. Andrews (1908) prepared a fairly comprehensive report on these strata and later workers (Walkom, 1914; Richards and Bryan, 1923, 1924; Browne, 1929; Reid, 1930; Sussmilch, 1935) based their discussions of the area on Andrews' work. Voisey (1936, 1939) studied the stratigraphy and palaeontology in more detail than did Andrews, showing that some of the fossiliferous beds were of Lower Permian age. Andrews had previously correlated the Drake rocks with the Lower Marine Beds of the Hunter River area (Clarke, 1878). Since Voisey's work little new information has been published on the geology of the Drake area; discussions in David (1950) and McElroy (1963) were based mainly on Voisey's information. At the present time the Bureau of Mineral Resources, in conjunction with the Geological Survey of Queensland, is engaged in regional mapping of the Warwick four-mile sheet which includes the Drake district. In 1968, while a post-graduate Honours student at the University of Queensland, the author mapped a thirty square-mile area of Permian strata, lying five miles west of Drake. The results of this work form the basis of the present paper which gives an account of the lithostratigraphy and biostratigraphy of the Drake area, revising age estimations and correlations by the above-mentioned workers in the light of more recently published literature on the Permian of eastern Australia.

Grid references cited herein refer to Military Sheet No. 1757 Drake 1 inch series, and are prefixed by the letters DK. The grid on the geological map of the Crooked Creek area (Fig. 1) corresponds to that of the military sheet. Figured fossil specimens are housed in the Department of Geology and

Mineralogy, University of Queensland. Fossil specimen numbers are prefixed by the letters UQF; fossil locality numbers are prefixed by UQL.



Text figure 1. Geological map of the Crooked Creek area, west of Drake, New South Wales.

Stratigraphy

The Drake area lies close to the western margin of the Clarence-Moreton Basin and the Permian sediments and volcanics form part of the pre-Mesozoic basement of this basin (McElroy, 1963). The strata are bordered in the east, west, and south by granitic rocks of the large New England Granite Batholith. North-north-east of Drake are Carboniferous strata, the Emu Creek Beds (Voisey *in* McElroy, 1963), whose relationship with the Permian rocks near Drake is not fully understood, while north-east of Drake, and separated from it by granite, are the Plumbago Creek Beds (Voisey, 1958) of Lower Permian age. Further north and east the Palaeozoic rocks are overlain by Jurassic conglomerates and sandstones of McElroy's (1963) Bundamba Group. In the mapped area west of Drake the rocks make up the following stratigraphic sequence (in descending order),

	GILGURRY MUDSTONE
BOOROOK GROUP	
	CATARACT RIVER FORMATION
CHEVIOT HILLS BEDS	

This sequence is somewhat different from those proposed by Andrews and Voisey (see Table 1). Reasons for these changes are explained in following descriptions of the rock units.

TABLE 1
Previous subdivisions of the Upper Palaeozoic sequence west of Drake

Age			Andrews 1908		Voisey 1936		Voisey 1958	
PERMIAN		TARTARIAN						
PERMIAN		KAZANIAN			?		?	
PERMIAN	ARTINSKIAN	"KUNGURIAN"			DRAKE SERIES	Upper Division	BOOROOK GP.	Gilgurry Mudstone
PERMIAN	ARTINSKIAN	"KUNGURIAN"			DRAKE SERIES	Upper Division	BOOROOK GP.	Cataract River Fm.
PERMIAN	ARTINSKIAN	BAIGENDZHINIAN		?	DRAKE SERIES	Lower Division	CHEVIOT HILLS GP.	Girard Pyroclastics
PERMIAN	ARTINSKIAN	AKTASTINIAN	DRAKE VOLCANICS	Newer Volcanic Series	DRAKE SERIES	Lower Division	CHEVIOT HILLS GP.	Drake Volcanics
PERMIAN		SAKMARIAN	DRAKE VOLCANICS	Older Volcanic Series	DRAKE SERIES	Lower Division	CHEVIOT HILLS GP.	Drake Volcanics
		UPPER CARBONIFEROUS	DRAKE VOLCANICS	Older Volcanic Series	?		?	
				?				

CHEVIOT HILLS BEDS

Name of Rock Unit: Andrews (1908) named the Palaeozoic rocks in the Drake area, the Drake Volcanics, and divided the sequence into the Older and Newer Volcanic Series. The former was considered an unfossiliferous unit consisting of lavas and pyroclastic rocks. Voisey (1936) named this unit the Lower

Division of the Drake Series and defined it as "several thousand feet of tuffs and agglomerates with occasional lava flows . . . exposed between Cheviot Hills and Crooked Creek". In 1958 Voisey changed the name of the unit to Cheviot Hills Group with two formations, Drake Volcanics and Girard Pyroclastics, which he did not define formally. The present study does not support the recognition of two distinct formations, so that the term "group" is inapplicable in this case.

Measurement of a complete stratigraphic section through the volcanics was not possible as the bottom of the unit was not present in the mapped area. Until an adequate type section is documented, the unit cannot be given formal formational status, and it is suggested that the name Cheviot Hills Beds should be employed.

Derivation of name: After Voisey (1958), from Cheviot Hills Homestead, 3 miles north of Drake.

Distribution: The Cheviot Hills Beds occur in three regions within the northern part of the mapped area (see Fig. 1). Outcrop is confined mainly to the valley of the Cataract River and some of its tributaries, especially Crooked Creek in its lower part (DK410241 to DK409256). The volcanic beds are reported to extend for about 8 miles east of the mapped area (sketch map *in* Voisey, 1936) and they are well-displayed in road cuttings along the Bruxner Highway.

Lithology: This unit is a sequence of lavas, tuffs, and agglomerates which display extreme variations in composition, texture, and overall structure. Most of the rock types are massive or thickly-bedded so that bedding is rarely apparent in outcrops. The lavas are usually of intermediate composition, but acidic and basic variants occur. Trachytic and trachyandesitic types are the most common; andesitic, trachyrhyolitic and rhyolitic forms are also present. Most of the lavas have a porphyritic texture although the rhyolites include massive, spherulitic, and banded varieties. Pyroclastic rocks vary from medium-grained feldspathic crystal tuffs to agglomerates with boulder-sized inclusions. Often tuffs and agglomerates are interbedded and contacts between them are sometimes gradational. Formation of the tuffaceous rocks was variable: some are entirely volcanic in origin, being composed mainly of small feldspar laths; others seem to be reworked, containing lithic fragments and detrital quartz grains which are the result of normal mechanical processes of erosion and deposition in an aqueous environment.

In a road cutting (at DK433144) on the Bruxner Highway a thin bed of crinoidal limestone is exposed. It is less than 12 inches thick, extends laterally for about 50 feet, and is underlain conformably by a fine-grained feldspathic tuff and overlain by agglomerate. As well as illustrating a local pause in volcanic activity, the limestone indicates that in this small area at least, laval and pyroclastic rocks accumulated in a marine environment.

Thickness: Voisey (1936) gave a thickness of "about 5000 feet" for the Cheviot Hills Beds, and although a full section through the unit is not present in the mapped area, the width of outcrop of volcanic rocks to the east (see sketch map *in* Voisey, 1936) indicates a very considerable thickness.

Fossil content: Crinoid plates, bryozoan fragments, and a single coral specimen doubtfully identified as *Euryphyllum* were recovered from the small limestone bed. Fragmentary bryozoan material was also discovered in a tuffaceous rock near a locality 2 miles south-west of Drake reported by Andrews (1908), and this is probably a localized occurrence similar to the above-mentioned limestone.

Stratigraphic relationships and age: Carboniferous and Lower Permian strata have been reported east of Drake (Voisey, 1958) but their relationships with the Cheviot Hills Beds are unknown. The Cataract River Formation which contains fossils of Upper Permian (? Kazanian) age (see section on palaeontology) seems to overly conformably the Cheviot Hills Beds so that the latter is probably Lower Permian to early Upper Permian in age.

Cataract River Formation

Previous reference: Voisey (1936) included this unit in the Upper Division of the Drake Series, but subsequently (1958) named this Division the Boorook Group with two formations, the older one being the Cataract River Formation.

Distribution: The formation outcrops in the north, central, and east-central parts of the mapped area (Fig. 1). Easterly extent of the unit is uncertain but it appears to thin out in this direction.

Lithology: The Cataract River Formation is a sequence of lavas and pyroclastic rocks interbedded with fossiliferous mudstones and cherts. As in the Cheviot Hills Beds, there are variations in composition and texture of the volcanic rocks, but the unit is characterized by obvious lateral continuity of its constituent beds, especially the mudstones. It is distinguished from the underlying Cheviot Hills Beds by this feature. Lavas of the Cataract River Formation are essentially similar to those of the Cheviot Hills Beds, although calc-alkaline types, such as rhyodacites and dacites predominate; andesitic and trachyandesitic types are less common. There is a slight gradation from intermediate to acidic lavas in ascending the formation. This is in contrast to the Cheviot Hills Beds in which vertical distribution of laval types is quite irregular.

Three types of tuff occur—lithic tuff, feldspathic crystal tuff and a hybrid variety that contains a mixture of tuffaceous and detrital materials. Agglomerates and volcanic breccias are common in the lower part of the formation; indeed, the basal beds are interbedded rhyolitic volcanic breccias and cherts, and they could be traced from Sawpit Gully, along the Cataract River (from DK382236 to DK387239), across a ridge about 2000 feet southwest of Red Rock mine, and into Crooked Creek (at DK409239).

Greenish-grey, calcareous mudstones are the most common detrital rocks, occurring in the lower 400 feet of the formation as beds up to 10 feet thick interspersed with volcanic material. Other thinner, discontinuous beds are present higher in the formation, as well as thin, irregularly-distributed beds of greenish chert and grey or brown, feldspathic sandstones.

Thickness: The type section as measured by Voisey (1936)—"down a spur leading into Sawpit Gully"—is approximately 810 feet thick. During the present study a section totaling about 920 feet was measured near the type locality. A much greater thickness (about 1600 feet) is estimated from outcrop along Crooked Creek, and it seems that the formation thins to the north-west.

Fossil content: The mudstones contain very rich brachiopod-bivalve-bryozoan assemblages while all other rock types, except for a bivalve-containing sandstone bed west of Sawpit Gully (at DK365255), are unfossiliferous. The faunas are described more fully in the section of palaeontology.

Age: Using faunal evidence summarized by Runnegar (in press), the age of the formation can be estimated as Kazanian; and isotopic age determinations of Permian rock units in various parts of the world may support the palaeontological deductions. Sylvinite from the Verkhnekamensk Formation, of the middle part of the Kungurian Stage in the U.S.S.R., has given an age of 240 million years (Smith, 1964). An age of 239 million years was reported by

Webb and McDougall (1967) from a biotite tuff at the top of the Gyranda Formation (Derrington, Glover, and Morgan, 1959) in the Bowen Basin. This formation lies above the Flat Top Formation (Derrington *et al.*, 1959), considered on the basis of its fossils to be of Kazanian age (Wass, 1965). This would indicate that many formations in eastern Australia, previously considered to be of Kazanian age, may be pre-Kazanian. However, there is some doubt as to the reliability of the Russian sylvinite age, and Webb (pers. comm.) considers likely an age of 250 million years for the Kazanian-Kungurian boundary. Such an age is not in conflict with the Kazanian age given to the Flat Top Formation, so it would seem that other formations correlated with this unit, e.g., Cataract River Formation, are also of this age.

Stratigraphic relationships: The Cataract River Formation conformably overlies the Cheviot Hills Beds, the basal beds being the rhyolitic breccias and cherts previously mentioned, and it is conformably overlain by the Gilgurry Mudstone.

Gilgurry Mudstone

Previous reference: Voisey (1936) included this unit in the Upper Division of the Drake Series. Subsequently (1958) he renamed this Upper Division the Boorook Group which he divided into two formations, the younger one being the Gilgurry Mudstone.

Distribution: The Gilgurry Mudstone makes up the entire southern one-third of the mapped area, and is well exposed along Slaty and Crooked Creeks, and in road cuttings on the Bruxner Highway. The rock unit extends about one mile east and five to six miles south of the mapped area; its northern extent is uncertain, although Voisey (1936) considered that it probably continued from near Sawpit Gully (see Fig. 1) to the Rivertree district, 20 miles north of Drake.

Lithology: The formation consists of grey to black, siliceous and calcareous mudstones, and light brown, feldspathic sandstones. Siliceous mudstone is most common, forming massive but intensely fractured beds, while the calcareous mudstone occurs as small lenses in the upper part of the unit; the sandstones form thin beds in the lower 500 feet of the unit.

Thickness: From outcrop along Slaty Creek a thickness of 1900 feet was estimated for the formation. This is much greater than Voisey's (1936) estimate of 1000 feet in the north of the present area of study, so it is probable that thinning of the rock unit to the north has occurred; easterly thinning is also evident.

Fossil content: The calcareous mudstone lenses contain rich brachiopod-bivalve assemblages, while brachiopods, bivalves, bryozoans and corals occur at several horizons in siliceous mudstone in the upper 500 feet of the formation. The sandstones are unfossiliferous. In the section on palaeontology, the faunas are discussed in more detail.

Age: Upper Permian (Kazanian). See the description of the Cataract River Formation for consideration of the problems associated with correlation and dating of Upper Permian rock units.

Intrusive Rocks

The western marginal portion of the area of study contains a coarse-grained biotite granite which constitutes part of the New England Batholith. The granite is poorly exposed in outcrops of large, rounded boulders, and usually has been intensely weathered. A small boss of molybdenite-bearing granite is present about a mile north of the mapped area, near the junction of Morgan's Creek and the Cataract River. These granitic intrusions are of Upper Permian to Triassic age as Jurassic sediments overly the granite near Rivertree (Voisey, 1939).

Three small, dolerite dykes occur in the north, east, and west of the mapped area. They are very poorly exposed in sporadic boulder outcrops.

Structure

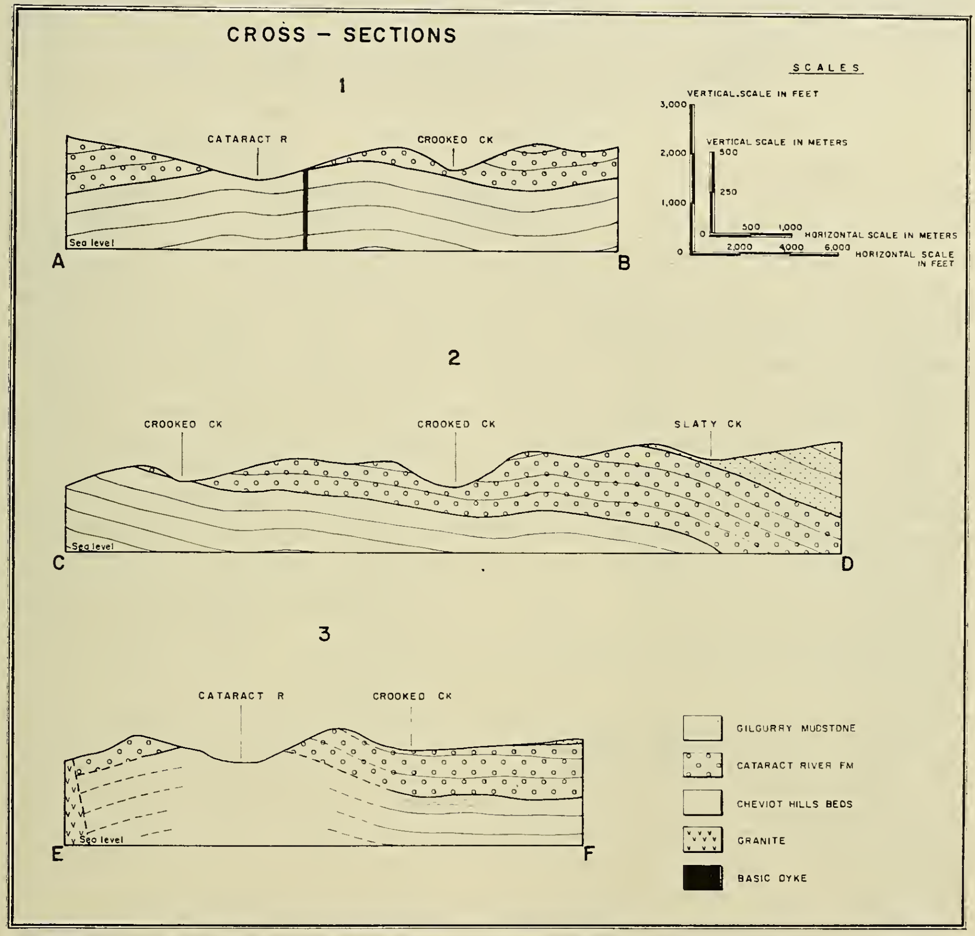
Strata west of Drake are gently folded and dips rarely exceed 20°. Together with the high relief of the area, the nature of the folding tends to make structural interpretation difficult, as too much emphasis may be placed on small dip readings whose magnitudes and widely varying bearings are due to minor, local adjustments of single beds, rather than major structural changes. Similarly, too much importance may be attached to small faults which are usually of limited extent. With recognition of any such contingent data the structure of the area appears fairly uncomplicated. Figure 1 illustrates the total structure while cross-sections 1–3 (Fig. 2) show the folding only.

Except for a large fault in the north-east (see Fig. 1), the dominant structural feature is a low anticline which extends almost the full length of the mapped area, and is bordered in the east by a narrow shallow syncline of smaller longitudinal extent. The anticline trends north-north-east with south-south-west plunge of approximately 20°. It is asymmetrical with beds on the western flank dipping at 15°–20° while beds of the eastern flank dip at 12°–16° and quickly pass into the synclinal structure. The crest of the anticline is broad and the axis of folding is slightly convex towards the east. Whether this structure extends beyond the northern extremity of the mapped area cannot be ascertained from aerial photographs, and previous workers have not reported its occurrence. Therefore, until further mapping is carried out in this northern region, continuation of the anticline is speculative. The syncline also trends north-north-east with its axis slightly convex to the east. It is a very narrow structure, plunging south-south-west at a slightly smaller angle than the anticline, and it is typical of the structure of the Drake area, whose Palaeozoic formations contain few folds of any magnitude.

Between these two main structures there is some minor folding, consisting of a system of small anticlinal and synclinal structures at right angles to the major elements (Fig. 2, cross-section 2). The system is best illustrated along Crooked Creek in mudstones of the Cataract River Formation. Along the Cataract River, east of the junction with Sawpit Gully (DK375243), are breccias and mudstones having a number of flexures which parallel the crest of the main anticline. They are of similar size and appearance to the minor folds in Crooked Creek, and their attitude indicates that they developed concomitantly with the major folds.

One large fault is present, trending at about 340° across the north-east corner of the mapped area (Fig. 1). On aerial photographs (1963, Warwick, Run 8, Nos. 132–136) it is well defined by a line of creeks and ridges, and it is slightly convex towards the east. West of Red Rock, along the fault zone, displacement of a mudstone bed of the lower part of the Cataract River Formation suggests that both vertical and lateral movement has occurred. Occurrence of such faulting corresponds with the distribution of minor faults and quartz veins in the area. These probably form part of the shear zone of the major fault.

Because of the massive or discontinuous nature of the volcanic beds, and intense fracturing of mudstones and other sediments, joint patterns are absent or quite irregular and are not an important structural feature of the rocks of the area. The massive nature of rock units also tends to mask the effect of small structural features such as the minor faults, so that on the geological map (Fig. 1), only those folds and faults whose trends could be accurately determined, are plotted.



Text figure 2. Cross-sections through the Crooked Creek area.

Palaeontology

Fossiliferous horizons mainly in calcareous mudstones are distributed through both the Cataract River Formation and Gilgurry Mudstone. Such horizons are well exposed along Crooked Creek, and in cliffs along the Cataract River. Other fossiliferous outcrops occur in road cuttings along the Bruxner Highway. Fossils have also been reported from the Cheviot Hills Beds (Andrews, 1908; Voisey, 1936). One locality near Drake (at DK445140) reported by Andrews, was also investigated and found to consist of sparsely fossiliferous tuffaceous rocks, the fossils being fragmental bryozoan and crinoidal material. This is probably a local development within the volcanic rocks analogous to the crinoidal limestone lens previously described in the section on stratigraphy (see p. 233).

Distribution of Species

Definition of biostratigraphic zones in the Permian strata of the mapped area is not possible because of the long-ranging nature, in this area at least, of many forms; the brachiopods *Cancrinella magniplica, Ingelarella mantuanensis, Notospirifer minutus, Trigonotreta* sp., *Terrakea solida,* and *Strophalosia ovalis,* and bivalves *Atomodesma* sp. and *Streblopteria engelhardti* are common in most fossiliferous horizons. One major faunal change is the appearance of tabulate corals, *Cladochonous nicholsoni* and *Thamnopora wilkinsoni* in the upper part of the Gilgurry Mudstone. Therefore, an informal

Table 2

Distribution of marine fossils in Permian strata, west of Drake

Thicknesses of rock and faunal units are not to scale

	Cheviot Hills Beds	Boorook Group		
		Cataract River Fm.	Gilgurry Mudstone	
	" Lower " Fauna			" Upper " Fauna
Stenopora cf. *S. tasmaniensis* Lonsdale, 1844	– – – –	———	———	———
Fenestella cf. *F. fossula* Lonsdale, 1844	– – – –	———	———	———
Euryphyllum sp.	– – – –	———	———	———
Streblopteria engelhardti (Etheridge & Dun, 1906)		———	———	———
Ingelarella mantuanensis Campbell, 1960		———	———	———
Terrakea solida (Etheridge & Dun, 1909)		———	———	———
Trigonotreta sp.		———	———	———
Cancrinella magniplica Campbell, 1953		———	———	———
Notospirifer minutus Campbell, 1960		———	———	———
Strophalosia ovalis Maxwell, 1954		———	———	———
Atomodesma sp.		———	———	———
Protoretepora ampla Lonsdale, 1844		———	———	———
Promytilus ? sp.		———	———	———
Streblochondria sp.		——		
Cancellospirifer maxwelli Campbell, 1953		——		
Aulosteges sp.		——		
Martinia sp.		—		
Strophalosia clarkei Etheridge, 1872		——	———	———
S. clarkei var. *minima* Maxwell, 1954		——	———	———
Aviculopecten cf. *A. farleyensis* Etheridge & Dun, 1906		——	———	———
Streptorhynchus sp.		——	—	
Ingelarella ingelarensis Campbell, 1960		—		
Subansiria sp.		—		
Gilledia sp.		—		
Aviculopecten cf. *A. lenuisulcus* (Dana, 1847)		—		
A. cf. *A. subquinquelineatus* (McCoy, 1847)		—		
Ptychomphalina sp.			———	———
Attenuatella multispinosa Waterhouse, 1967			—	
Walnichollsia subcancellata (Morris, 1845)			—	
Cladochonous nicholsoni (Etheridge, 1914)				———
Thamnopora wilkinsoni (Etheridge, 1891)				———
Ingelarella havilensis Campbell, 1960				———
Fusispirifer sp.				———
Peruvispira sp.				———
Calceolispongia sp.				———

method of subdivision is to consider that the sequence west of Drake contains two faunas, an "upper" one containing the above-mentioned corals and a "lower" one without these corals. The "lower" fauna is distributed through more than 3000 feet of section, extending from an uncertain position in the Cheviot Hills Beds to 1400 feet above the base of the Gilgurry Mudstone. The "upper" fauna is restricted to the upper 400–500 feet of the Gilgurry Mudstone. Table 2 gives a list of identified fossil species from the mapped area, showing their distribution within the Permian strata and also indicating the informal faunal divisions.

Faunal Correlations

Dickins (*in* Malone, Corbett, and Jensen, 1964) distinguished, in the northeastern part of the Bowen Basin, a sequence of four Permian, marine faunas which in ascending stratigraphic order he termed Faunas I, II, III and IV. Fauna III, which had been further subdivided in its type area to IIIa, IIIb, and IIIc (Dickins *in* Dickins, Malone, and Jensen, 1964), has not been recognized outside the Bowen Basin, while Fauna I is very similar to Fauna II and could either be considered a subdivision of Fauna II, or disregarded altogether (Dickins *in* Dickins *et al.,* 1964). Other distinct assemblages, the Allandale fauna and Ulladulla fauna (= *Eurydesma-Myonia corrugata* fauna), have been recognized in the Sydney Basin, and the former also occurs in Tasmania (Runnegar, 1967a; in press).

The faunas in the sequence west of Drake contain a number of species that are characteristic of Fauna IV. These include *Streblopteria engelhardti, Aviculopecten* cf. *A. tenuisulcus, Strophalosia ovalis, S. clarkei, S. clarkei* var. *minima, Terrakea solida, Ingelarella mantuanensis, I. havilensis,* and *Notospirifer minutus.* Except for *I. havilensis* which is confined to the upper part of the Gilgurry Mudstone, these forms range throughout the Drake sequence (see Table 2). *Cancrinella magniplica*, an extremely common element of the Drake faunas, and *Ingelarella ingelarensis,* a less common species at Drake, have also been reported from Fauna III (Runnegar, 1967b). In spite of this, the fauna containing the above-mentioned species is correlative with Fauna IV. The myalinid bivalve *Atomodesma* sp., which is very common in the faunas west of Drake, is similar to *Atomodesma (Aphanaia)* sp. (Hill and Woods, 1964, pl. 11, figs. 6, 7) from the Oxtrack Formation near Cracow and *Atomodesma* ? sp. nov. (Runnegar and Ferguson, 1969, p. 254) from the "upper brachiopod fauna" of the South Curra Limestone at Gympie. Both these occurrences are in fossil assemblages typical of Fauna IV. The present author has also recognized similar forms of *Atomodesma* in the Wallaby Beds, south of Warwick (at UQL3030), which contain a Fauna II assemblage (Armstrong, 1966); but, because of its more widespread occurrences in typical Fauna IV assemblages, *Atomodesma* sp. appears more characteristic of the younger fauna. Voisey (1936) recorded the presence of *Taeniothaerus subquadratus* (Morris, 1845) in a collection from the Cataract River Formation in Sawpit Gully. This species is diagnostic of Fauna II (Runnegar, 1967b) and its association with the previously-mentioned Fauna IV elements would appear quite extraordinary. However, examination of Voisey's specimen (F36345, Australian Museum Collection) by the present author showed that it is referable to the genus *Aulosteges* von Helmersen, 1847, an uncommon brachiopod in eastern Australia. From the available information it is quite apparent that the faunas of the sequence west of Drake are equivalent to Fauna IV and, following Runnegar (1967b), they may be assigned an Upper Permian (Kazanian) age. This enables correlation of the Cataract River Formation and Gilgurry Mudstone with other rock units in eastern Australia known to contain fossils pertaining to Fauna IV, especially those in the well-documented Bowen and Sydney Basins (see Runnegar, 1967b, p. 553 for a list of such units).

The appearance of *Attenuatella multispinosa* in the upper part of the Gilgurry Mudstone (see Table 2) enables correlation of this unit with the AG4 limestone of the Arthurton Group in New Zealand (Waterhouse, 1964). The New Zealand formation contains *A. incurvata* Waterhouse, 1964, to which *A. multispinosa* is very similar (Armstrong and Telford, 1969), as well as *C. magniplica*, *I. mantuanensis* and *I. havilensis* that are also common in the Gilgurry Mudstone.

Regional Relationships

Although faunal correlations of the Permian strata west of Drake can be made with some accuracy, structural relationships with other nearby areas containing Upper Palaeozoic sediments are uncertain. Voisey (1936, 1939) showed that epi-Permian tectonic activity in the Drake area decreased in intensity from east to west, as evidenced by the decrease in dips of the strata from east to west. Therefore, the structure of the region east of Drake is more complex than that of the present area of study, making formational contacts difficult to interpret. The steeply-dipping, Carboniferous Emu Creek Beds, situated about eight miles north-north-east of Drake were thought by Voisey (1939) to be faulted against the Cheviot Hills Beds. Voisey had little positive evidence for this idea, and no further information has been published about the Emu Creek Beds, so their contact relationships with the Permian strata remain uncertain. The Plumbago Creek Beds, also a relatively steeply dipping unit, lie about ten miles north-east of Drake and, according to the species list of Voisey, (1958, p. 180), contain a fossil fauna typical of Dickins' (1964) Fauna II (Lower Permian). Hence these beds are older than the Cataract River Formation and Gilgurry Mudstone, and older than or time-equivalent to the Cheviot Hills Beds. The Plumbago Creek Beds consist of limestone interbedded with hornfelsed mudstones and cherts, indicating a different environment of deposition from that of the dominantly volcanic Cheviot Hills Beds. However, a granitic intrusion separates these two rock units, and their structural relationships are obscured.

Permian strata extend to the Rivertree and Undercliffe Falls areas, twenty miles north of Drake. Little work has been done between Drake and these areas so that the stratigraphic relationships of their strata is not known.

An isolated area of Permian sediments has been reported at the homestead of Maryland near the Queensland border, north-east of Stanthorpe (Voisey, 1939). The sediments, which are completely surrounded by granitic rocks, have been altered by contact metamorphism, but Voisey noted the presence of the brachiopod *Anidanthus springsurensis* (Booker, 1932), a diagnostic element of Dickins' (1964) Fauna II. Another small area of possible Permian strata was seen by the present writer in Queensland near Dalveen, about ten miles north of Stanthorpe. The strata are unfossiliferous, consisting mainly of volcanic rocks, so that there is some doubt as to their age. In some respects the situation is similar to that at Maryland, as the volcanic rocks are almost completely surrounded by granitic rocks; they are partly overlain, unconformably, by Mesozoic sandstones. Both these isolated Permian blocks can be considered as roof pendants in the New England Batholith and, as such, their relationships with the Drake sequence cannot presently be determined accurately.

Another nearby area of Permian sedimentation is that south of Warwick in southern Queensland, where several fault-blocks containing Permian sediments and volcanics are present, and are surrounded by sediments and volcanics of the Devonian Silverwood Group (Lucas, 1959). Richards and Bryan (1924) considered the possibility that the Permian strata at Drake had suffered large-scale block-faulting, similar to the process by which the Warwick fault blocks were formed. However, on the basis of fossil evidence, Richards and Bryan did not think the sediments of the two areas could be correlated. Voisey (1936) did not think the Drake strata were contained in fault-blocks, but he did contend that the Permian sequences at Warwick and west of Drake could be correlated "in a broad sense". The present study at Drake also did not produce evidence for block-faulting. Recent work in the Warwick area by Dr. J. Armstrong of the University of Queensland partly confirms Voisey's correlations, although some discrepancies remain. Voisey dated the rocks of the two areas as Lower Permian and (1939) considered that beds of the Condamine Block (Condamine Beds) and Stanthorpe Road Block (Wallaby Beds) near Warwick were equivalents of part of the Upper Division of the Drake Series (Boorook Group). However, in the present study, units of the Boorook Group (Cataract River Formation and Gilgurry Mudstone) have been shown to contain Upper Permian faunas (see section on palaeontology), and fossils typical of Dickins' (1964) Fauna IV, which is of Upper Permian age, have been found in the Condamine Beds (Armstrong, 1966). The lithological-faunal association in these beds is also similar to that west of Drake, with the fossils enclosed in massive, dark-grey mudstones. While this information agrees with Voisey's correlation of part of the Boorook Group and the Condamine Beds, it is in conflict with his age determinations. On the other hand, the remaining fault-blocks, including the Stanthorpe Road Block, do contain Lower Permian fossils (Armstrong, 1966) but strata within the blocks do not seem to be obvious lithological correlatives of the sequence west of Drake; according to their faunas they could be partly equivalent to the Plumbago Creek Beds, north-east of Drake. Thus, while some correlation of the Drake and Warwick Permian sequences is possible, much additional work is required in these areas before definite relationships can be established.

It can be concluded then, that faunal correlations of the Drake sequence with Permian strata in other nearby areas can be made fairly accurately, but structural relationships are much more difficult to determine, and will remain so until detailed geological mapping is carried out in the intervening regions.

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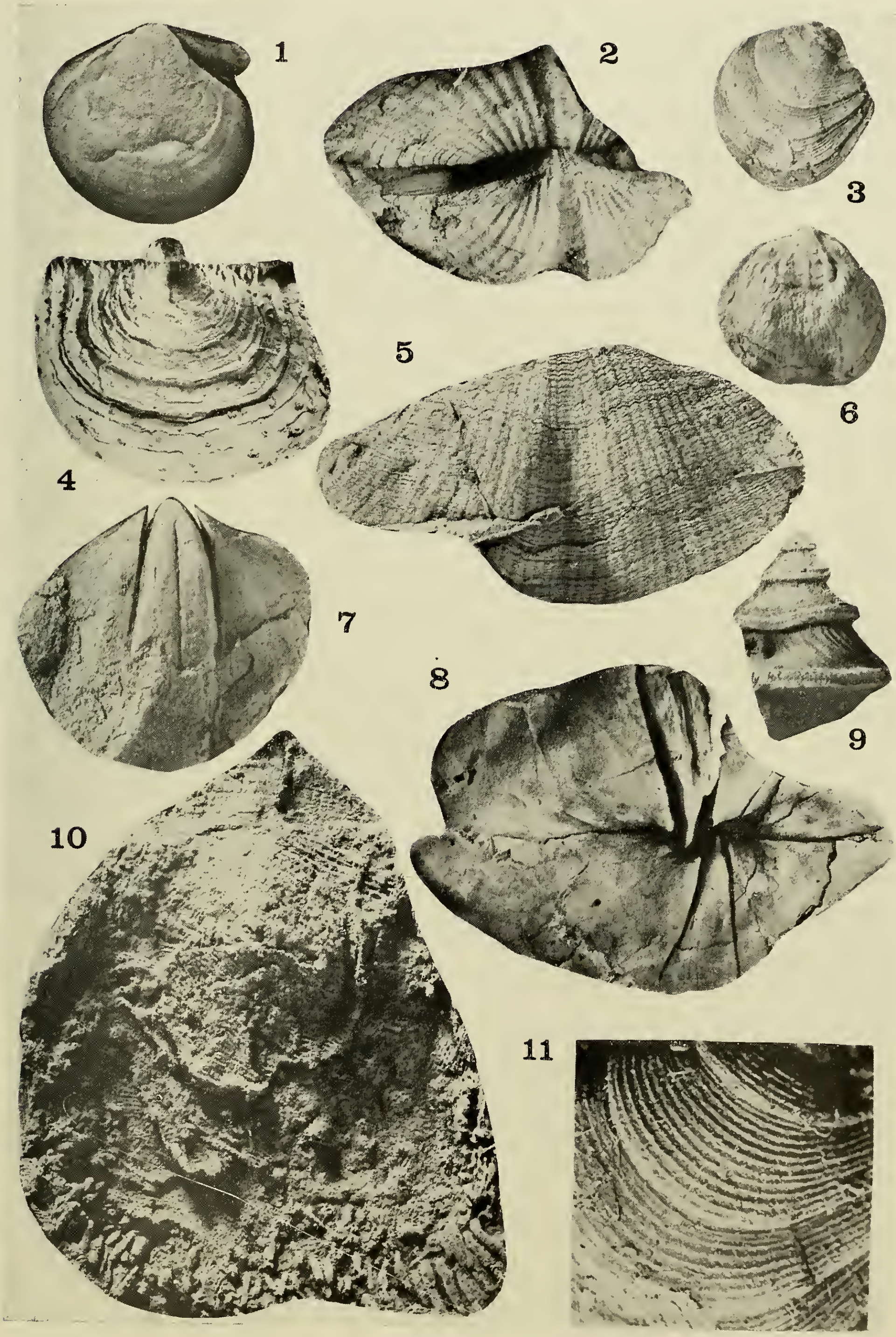
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